THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants:	Patrick T. RIGNEY Bobby L. GOIN Jesse G. McLAWHORN Gary L. VADNAIS
Title:	HIGH INTEGRITY POLYESTER STRAPPING
Serial No.:	10/510,550
Filing Date:	09 June 2005
Customer No.:	42419

DECLARATION OF DR. PATRICK T. RIGNEY

I, Dr. Patrick T. Rigney, declare as follows in regard to the above-identified United States patent application.

1. I am employed by Illinois Tool Works, Inc. ("ITW") in the ITW Technology Center. I am currently a Research Associate and Project Manager in areas relating to Polymer Technology. I have been employed by ITW for nine years.

2. I earned a Ph.D. in Chemical Engineering (Polymers) from North Carolina State University in Raleigh, NC. I earned a M.S. in Chemical Engineering from University of Notre Dame in South Bend, IN. I earned a B.S. in Chemical Engineering from University College in Dublin, Ireland.

3. I am an inventor in the above-identified United States patent application. The claimed invention is directed to an improved polyester strapping

of the type which is molecularly oriented by stretching in the longitudinal direction of the strapping, and has a width of 0.5-3 cm and a thickness of 0.03-0.20 cm. The improvement relates to the inclusion of a minor amount of one or more chemically unmodified polyolefins which can be linear low density polyethylene, branched low density polyethylene, high density polyethylene, polypropylene, or a combination of these polyolefins.

4. Polyester strapping having the aforementioned molecular orientation and dimensions is used for heavy duty applications including unitizing forestry products or lumber, large bales of synthetic fibers or cotton, bricks, metals, etc. for road and rail transport. When used in these applications, the polyester strapping is affixed under high longitudinal tension, and/or is subjected to high longitudinal tension during lifting and transportation of heavy items. One problem associated with the use of polyester strapping in these applications has been spontaneous longitudinal splitting of the strapping especially during installation or sudden unloading. In other words, a single polyester strap having the aforementioned orientation and dimensions may longitudinally split into two or more segments having smaller dimensions when under high tension. This longitudinal splitting compromises the strength and integrity of the polyester strapping and undermines the security of the heavy items being packaged and moved. The application of strapping bands to unitize and stabilize the load requires the use of special strapping head tools or machinery to produce weld joints for split resistant polyester strapping.

5. We have found that mixing the claimed unmodified polyolefins into the polyester in the claimed amounts (about 0.2-2.8% by weight) increases the resistance of the polyester strapping to longitudinal splitting, and reduces or eliminates the incidences of longitudinal splitting during strap tensioning, welding and loading/transporting operations, while maintaining acceptable weld strength and other properties. This result is surprising and unexpected because polyolefins are known to be thermodynamically incompatible with polyesters, and do not mix or disperse very well in polyesters. When two thermodynamically incompatible polymers are mixed, the natural and expected result is that any strapping, film, tube or sheet material made from the mixture would have an increased tendency to split, fracture, break or fibrillate, compared to a strapping, film, tube or sheet material similarly made from either polymer without the other. Moreover, the amounts of unmodified polyolefin are easy to analyze and the results can be readily verified.

6. In order to verify the improved resistance to longitudinal splitting resulting from the inventive strapping, a series of trial runs were performed using a standard Signode production line for polyester strapping. Using standard production conditions, strapping was made using the following polyester and different levels of the following polypropylene ("PP") and linear low density polyethylene ("LLDPE") additives:

Polyester:	Primarily polyethylene terephthalate ("PET") having a low Inherent Viscosity or IV (0.70-0.78 deciliters/gram), recycled bottle flake from Signode's Florence, Kentucky recycling plant.
PP:	Homopolymer, melt flow rate (230°C) = 1.3 grams/10 min, no chemical modification, type F013M, available from Suncoco
LLDPE:	Ethylene-alpha olefin copolymer, melt index (190°C) = 1.0 grams/10 min, no chemical modification, type LL1001.32, available from Exxon-Mobil Chemical Co.

7. The polypropylene was added to the polyester at levels of 0, 0.5, 1.5, 2.0, 2.8, 3.5 and 4.5% by weight. At each level, oriented polyester strapping was prepared having an oriented length of about five times an initial unstretched length, a width of about 1.5 cm, and a thickness of about 0.09 cm. Five strapping samples were evaluated for each level of additive. The samples were tested for peak load and elongation at break using ASTM D3950 and an INSTRON® 4467 testing machine. The samples were also tested for longitudinal strap splitting and longitudinal weld splitting using a split tester that included pneumatically driven needle penetrometer. Other properties (below) were tested using International Standards Organization ("ISO") 9001 procedures.

The split tester instrument includes a guide plate for holding a strapping sample and a downward moving penetrator. The guide plate includes a channel for inserting a typically 150 cm long strapping sample. The width of the channel is selected to accommodate the width of the strapping sample. The

strapping sample is inserted into the channel and the guide plate is clamped to secure the strapping sample in place on both ends. If the split resistance of a welded region is being tested, then the welded region must be part of the sample that is inserted into the channel.

The penetrator has a sharp point defined by a maximum radius of 0.127 mm. The penetrator is mounted to a pneumatic plunger cylinder having a controlled downward movement. The plunger cylinder is gradually lowered until the penetrator tip contacts the strapping sample mounted to the guide plate and applies a controlled downward pressure that is sufficient to puncture the strapping and may reach about 80-100 psi.

The penetrator tip punctures the strapping and the strapping is advanced manually a distance of approximately 10 cm before the next puncture is made. If the penetrator tip merely punctures the strapping, then no longitudinal split is recorded. If the puncturing of the strapping causes a longitudinal split to occur, then a longitudinal split is recorded. This procedure is repeated at least five times using at least five samples of strapping in order to determine the frequency of splits for a particular type of strapping.

8. The following results were obtained for the polyester strapping samples using the PP additive. These laboratory tests were performed at the time of the extrusion/orientation trial.

TABLE 1: EVALUATION OF STRAPPING USING PP ADDITIVE

Coil #	Percent Additive	No. of Samples	Width, cm	Std. Dev.	Gauge, cm	Std. Dev.	Peak Load Lbs	Std. Dev.	Tensile KPsi	Std. Dev.	% Elongation at Break	Std. Dev.	Strap Splits	Weld Splits
M-1	0.0	5	1.535	.0142	.0889	.0008	1486	70	70.2	3.6	13.1	1.1	10/10	5/5
M-2	0.5	5	1.540	.0318	.0899	.0020	1503	60.5	70.3	5.8	13.5	2.3	10/10	5/5
M-3	1.5	5	1.550	.0210	.0917	.0005	1486	82.3	67.5	3.6	12.8	1.6	0	0
M-4	2.0	5	1.545	.0193	.0917	.0018	1452	41.4	66.0	1.7	12.0	1.1	0	0
M-5	2.8	5	1.546	.0172	.0912	.0015	1453	68.7	66.5	3.9	13.3	2.0	0	0
M-6	3.5	5	1.542	.0246	.0904	.0015	1410	23.3	65.2	2.6	14.4	2.5	0	0
M-7	4.5	5	1.545	.0300	.0922	.0013	1370	23.1	62.1	2.3	13.6	1.6	0	0

As shown above, the longitudinal splitting of the polyester strapping decreased due to the additive, and became nonexistent at additive levels of 1.5% and higher. However, the peak load (break) strength declined significantly at additive levels above 2.8% by weight. This data supports the claimed range of 0.2-2.8% by weight additive, and suggests that levels of about 1.5% by weight are optimal.

9. The foregoing and other tests were repeated twelve days after the extrusion/orientation trial in order to verify the results over time. The following results were obtained.

TABLE 2: EVALUATION OF STRAPPING USING PP ADDITIVE

Coil # (5 samples each)	Percent Additive	Width, cm	Std. Dev.	Gauge, cm	Std. Dev.	Peak Load Lbs	Std. Dev.	Tensile Kpsi	Std. Dev.	% Elongation at Break	St. Dev.	Strap Splits	MHT-80 Weld Splits	Z-20 Weld Splits	MHT-80 Weld Strength Lbs	Z-20 Weld Strength Lbs
M-1	0	1.530	.0198	.0881	.0020	1436	36.9	69.5	2.6	12.9	2.0	10/10	5/5	5/5	1202	1158
M-2	0.5	1.548	.0274	.0883	.0008	1419	31	66.0	2.8	13.6	1.9	0	5/5	5/5	1184	1183
M-3	1.5	1.541	.0363	.0886	.0018	1407	28.3	66.6	3.2	12.6	1.3	0	0	2/5	1174	1181
M-4	2.0	1.538	.0434	.0881	.0013	1370	44.2	63.9	4.0	12.1	2.0	0	0	0	1111	1113
M-5	2.8	1.530	.0182	.0904	.0010	1396	19.2	65.1	1.7	12.4	1.3	0	0	0	703	727
M-6	3.5	1.546	.0368	.0906	.0020	1364	42.4	62.8	4.2	14.3	1.6	0	0	0	574	532
M-7	4.5	1.562	.0302	.0917	.0023	1322	30.2	59.6	3.5	13.9	2.0	0	0	0	No Weld	438

As shown above, the longitudinal splitting of the polyester strapping decreased and became nonexistent in the region outside the weld at additive levels of 0.5% and higher. When a MHT-80 weld head was used, the longitudinal splitting in the welded area decreased and became nonexistent at additive levels of 1.5% and higher. When a Z-20 weld head was used, the longitudinal splitting in the welded area decreased at an additive level of 1.5% and became nonexistent at levels of 2.0% or higher.

However, at additive levels of 2.8% and higher, the weld strength for both types of weld head fell dramatically. Without sufficient weld strength, the polyester strapping would be inoperable. The overall date supports the claimed range of 0.2-2.8% by weight additive, and suggests that levels of about 1.5%-2.0% PP are optimal.

10. Similar experiments were performed using the LLDPE additive. The LLDPE was added to the polyester at levels of 0, 0.5, 1.5, 2.0 and 2.8% by weight. At each level, oriented polyester strapping was prepared having an oriented length of about five times an initial, unstretched length, a width of about 1.5 cm, and a thickness of about 0.09 cm. Five strapping samples were evaluated for each level of additive. The samples were evaluated using the test procedures described above in Paragraph 7. The following results were obtained using tests performed at the time of the extrusion/orientation trial.

TABLE 3: EVALUATION OF STRAPPING USING LLDPE ADDITIVE

Coil #	Percent Additive	No. of Samples	Width, cm	Std. Dev.	Gauge, cm	Std. Dev.	Peak Load Lbs	Std. Dev.	Tensile KPsi	Std. Dev.	% Elongation at Break	Std. Dev.	Strap Splits	LattaWeld Splits
P-1	0	5	1.539	.0193	.0897	.0013	1548	114	70.4	4.3	12.6	0.5	10/10	5/5
P-2	0.5	5	1.533	.0239	.0892	.0117	1483	39.5	69.9	1.9	11.9	2.3	1/10	5/5
P-3	1.5	5	1.550	.0025	.0899	.0011	1384	37	64.1	1.5	12.9	1.5	0	4.5/5
P-4	2.0	5	1.554	.0114	.0909	.0013	1311	18.9	59.9	1.6	16.6	3.0	0	2/5
P-5	2.8	5	1.553	.0178	.0898	.0011	1313	25.4	60.7	1.4	13.6	2.4	0	0

As shown above, the longitudinal splitting of the polyester strapping decreased substantially at an additive level of 0.5% and became nonexistent at additive levels of 1.5% and higher, in the areas not influenced by the weld. In the welded regions, the longitudinal splitting diminished at 2.0% additive and became nonexistent at 2.8% additive, suggesting that the LLDPE additive is optimized at about 2.0-2.8% by weight. As noted below, the weld strength diminishes above 2.0% LLDPE additive, and welding becomes more difficult.

11. The foregoing and other tests were performed twelve days after the extrusion/orientation trial in order to verify the results over time. The following results were obtained.

TABLE 4: EVALUATION OF STRAPPING USING LLDPE ADDITIVE

Coil # (5 samples each)	Percent Additive	Width, cm	Std. Dev.	Gauge, cm	Std. Dev.	Peak Load Lbs	Std. Dev.	Tensile Kpsi	Std. Dev.	% Elongation at Break	St. Dev.	Strap Splits	MHT-80 Weld Splits	Z-20 Weld Splits	MHT-80 Weld Strength Lbs	Z-20 Weld Strength Lbs
P-1	0	1.543	.0437	.0876	.0008	1458	67.3	69.6	5.3	12.8	2.4	10/10	5/5	5/5	1174.2	1161.9
P-2	0.5	1.530	.0282	.0881	.0020	1434	37	68.7	4.2	12.6	1.3	7/10	5/5	5/5	1185.9	1150.7
P-3	1.5	1.573	.0168	.0902	.0127	1302	33.6	59.3	2.7	14.2	1.0	0	1/5	2/5	1143.9	1133.2
P-4	2.0	1.549	.0201	.0904	.0020	1307	29.1	60.3	3.0	12.2	1.2	0	0	0	1110.6	1077.2
P-5	2.8	1.547	.0196	.0889	.0010	1268	16.2	59.5	1.4	12.3	1.1	0	0	0	921.1	Not Measured

Based on these tests, the longitudinal split resistance in the non-welded and welded portions of the strapping was optimized at about 2.0% by weight LLDPE additive level. At the higher level of 2.8% by weight, the weld strength of the strapping diminished rapidly for the MHT-80 weld and was inadvertently not measured for the Z-20 weld. For this reason, higher levels above 2.8% by weight were not attempted. All tests used the weld heads set at the same conditions (weld cycle time, cooling time, pretension) to focus on additive dose level effects instead of weld setting optimization.

12. All statements herein based on my own knowledge are true, and all statements made on information and belief are believed to be true. I acknowledge that willful false statements and the like are punishable by fine or imprisonment. or both (18 U.S.C. § 1001) and may jeopardize the validity of this patent application or any patent issuing thereon.

Respectfully submitted,

Patrick T. Rigney

Patrick T. Rigney

Date: 5-15-09